Lagrangian and Model Based Studies of the Arabian Sea

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LONG-TERM GOALS

The long-range aim of this research is to improve the understanding of marine population dynamics and the interaction between organisms and their physical environment. This goal is pursued through a combination of data analysis and model development.

OBJECTIVES

The specific objective of this research is to produce a synthesis of the current knowledge of the dynamics of the Arabian Sea. In particular, the dynamics of populations of phytoplankton and zooplankton associated with western boundary, Oman coastal and open ocean upwelling in this region are being studied. The goal is to produce a model framework that can be used to test hypotheses arising from the analysis of the 1995 field work and earlier data sets. The results of the model and data analysis are then compared with other upwelling regimes.

APPROACH

The objectives of the study of the Arabian Sea are being pursued using a combination of data collected since 1995 in the region and a coupled biophysical model. The data sets include five years of drifter data collected as part of WOCE (joint ONR/NSF funded), a decade worth of satellite imagery and historical hydrographic data. Biological data is being considered in cooperation with G. Hitchcock and S. Smith. The basic physical model being used is a regional MICOM simulation using the global model (R. Bleck) as boundary conditions. Funding for the physical model development is from U.S. WOCE (NSF). The current effort has added a set of biological models to the mixed layer and upper thermocline of the physical model. The first component is a two food-chain plankton model parameterized to include both a copepod chain and a microbial chain. In order to more fully explore the population biology of *Calinoides carinatus*, an age/metabolic structured model has been implemented on Lagrangian particles. This model is a modified version of the Calanus model developed with M. Pascual and C. Davis. It is modified using laboratory results on *C. carinatus* from German and South African workers. The model also includes a new parameterization of diapause that allows it to explore different cues that the copepod might be using to control this portion of its life cycle.

WORK COMPLETED

The basic model development has been completed and a number of simulations run. The model has been verified by comparison of its sea surface temperature cycle and the formation of upwelling

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filaments. Supplemental NASA funding has allowed model runs with a suite of seven different wind products. This allows us to use the NCEP and NSCAT winds that produce the best results. Model runs have been carried out for five years to demonstrate the ability to produce a sustained ecosystem and to investigate interannual variability tied to changes in the monsoon forcing. Initial investigations using the Lagrangian model on particles seeded into the MICOM and on actual WOCE/SVP drifters have been used to consider the diapause and foraging behavior of *C. carinatus.*

RESULTS

The two food-chain runs produce a fairly realistic portrayal of conditions in the Arabian Sea. The model shows that the larger zooplankton are severely restricted in the inter-monsoon periods. Remnant eddies around the mouth of the Gulf of Aden produce enough production to allow a copepod population to persist during these highly oligotrophic periods. With the onset of the monsoons macrozooplankton spread out with the modest bloom in the NE monsoon and a large bloom during the SW monsoon. When the copepods are allowed to graze on the microzooplankton the latter are kept to low concentration except in the deep chlorophyll maxima that develops in the model thermocline layers. These layers with oligotrophic mixed layers dominate in the offshore waters.

The Lagrangian population model for *C. carinatus* has lead to several interesting findings. The first is that the populations of this upwelling endemic differ in their thermal response around Africa. The *C. carinatus* in the Somali and Omani upwelling zone is adapted to warmer conditions than their West African and Benguela branches. In the surface layers, a thermal or food related cue for diapause are both consistent with observed population distributions. The best model for the termination of diapause seems to be a paramterization that takes into account the use of lipid reserves as a cue. An explicit parameterization of the induction of a hormonal response to lowering lipid content has been developed in cooperation with S. Smith's post-doc N. Idrisi. Initial runs on simulated trajectories in the biologically coupled MICOM shows that the phytoplankton resources are adequate to produce diapause capable *C. carinatus*. Simulations of diapaused animals between 700 and 1500 m depths in the model suggest that an adequate portion of *C. carinatus* is retained for the nine months between successive SW monsoons. Interestingly, the diapaused trajectories show an introduction of animals into the equatorial currents where they might produce a connection to the populations of *C. carinatus* off Java. No trajectories, however, carry the organism to the upwelling centers off southern India where *C. carinatus* is not found. Finally, significant numbers are entrained into the Gulf of Aden where the 1994-95 field work found significant numbers.

IMPACT

The modeling effort supported by this award continues to attract attention. Brazil and Japan have funded trips for the P.I. to talk about the model at the University of Sao Paulo and Tokyo. Several investigators in Europe have requested the model or its POM variant. The earlier URIP supported work on fish schooling using a variant of the Lagrangian code has been quoted in several NOAA/NMFS reports.

TRANSITIONS

Discussions are underway with J. Kindle (NRL) concerning collaborative work. Conversations have occurred with M. Clancy about what would be needed to expand the Lagrangian code for Search and Rescue applications.

RELATED PROJECTS

The intellectual thrust of this project has extended to two students, one funded by the Brazilian government and one by the U.S. Coast Guard. The Brazilian student will defend his Ph.D. in the spring. His work involved the development of the dual food-chain model and implementing it in a POM model. The Coast Guard officer completed her M.S. within the allowed billet. Her work involved using the Lagrangian code and a variety of current products to predict the drift of SAR targets in the Gulf Stream region. A short description of her work is in press in Naval Proceedings. She is currently assigned to the R&D center in Groton where she is continuing her SAR work.

PUBLICATIONS

Peng, G., D.B. Olson, O. Esenkov and G. Samuels, 1997. Simulated Oceanic Response to Various Atmospheric Forcings in the Arabian Sea Coastal Region. In: 1997 Spring Meeting. EOS Trans., AGU. May 27 - 30, 1997, Baltimore, Maryland. (Abstract)

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